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Commentary: Functional Ankle Instability Revisited

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Chronic ankle instability is a clinical problem frequently seen in athletes. Various complicated mechanical and neuromuscular factors seem to be involved in chronic ankle instability. The purpose of this special communication is to revisit the concept of functional ankle instability and to discuss its clinical relevance. The 2 hypothesized causes of chronic ankle instability have been labelled mechanical instability and functional instability. Mechanical instability (MI) is defined as ankle movement beyond the physiologic limit of the ankle's range of motion. The term ''laxity'' is often used synonymously with MI. Functional instability (FI) is defined as the subjective feeling of ankle instability or recurrent, symptomatic ankle sprains (or both) due to proprioceptive and neuromuscular deficits.

FUNCTIONAL BIOMECHANICS OF ANKLE INSTABILITY

It is not possible to discuss FI without first understanding the biomechanics related to lateral ankle instability. (Please note that the relevant anatomy has been described elsewhere in this special issue.) While the talocrural joint is often considered ''the ankle joint,'' it is important to recognize that the subtalar joint is critical to the mechanics of ankle instability. The subtalar joint acts functionally as a mitered hinge, allowing the leg to rotate on the weight-bearing foot. While the body's center of gravity moves forward during walking and running, the stance limb is positioned so that the supportive area is situated beneath the center of gravity (COG). Biomechanically, the reaction force from the ground acts on the foot to create a moment acting on the subtalar joint.

The position of the foot in relation to the COG affects the ground-reaction force acting through the center of pressure (COP) (Figure 1). Postural corrections at the ankle primarily occur at the subtalar joint as rotations occur around the COP. Ankle synergy is defined as postural corrections taking place at the ankle; these primarily occur through corrective motions of inversion and eversion in an effort to keep the foot stable underneath the COG. If pure ankle synergy takes place, no shear forces are produced, and any forces on the foot are counteracted by forces acting through the COG.

The relationships of the muscles around the ankle and the axes of the subtalar and talocrural joints usually define the joint's ability to counteract external loads (torques) on the ankle. Torque around the ankles depends on the line of action of the ground-reaction force upon the subtalar-joint axis. The ground-reaction force typically acts lateral to the subtalar-joint axis and anterior to the talocrural-joint axis (Figure 2). The external load usually everts and dorsiflexes the ankle. This torque is counteracted by the strong plantar-flexor and invertor muscles.[1]

The subtalar-joint axis is typically 42° from the horizontal axis of the foot and 23° from the longitudinal axis of the foot, passing just medial to the anterior tibial tendon.[2] Gauffin[3] showed that the subtalar-joint axis moves during the stance phase of gait. When the foot is everted, the subtalar-joint axis moves medially, and when the foot is inverted, the axis moves laterally (Figure 3). The inverted, weight-bearing ankle is likely to produce an external load that further forces the foot into inversion. The evertor (or pronator) muscles are not thought to be strong enough to withstand a body-weight load acting with a lever longer than 3 to 4 cm. If a shear force is added, the torque rises rapidly and an episode of hyperinversion and subsequent ''giving way'' of the ankle is likely to occur.

In barefoot conditions, the ankle normally avoids an external inverting torque because the line of action of the reaction force is seldom far from the subtalar axis. The simple illustrated series (Figure 4) shows that the hyperinverted ankle has created an external inverting torque, which is potentially injurious. A shoe may make the foot more vulnerable to hyperinversion because the added breadth of the shoe increases the length of the lever arm, and friction between the shoe and the ground adds a shear (horizontal)-force component, thus creating more torque about the subtalar joint. In a traumatic situation, an external inversion torque typically starts the mechanism of injury. If the evertor muscles cannot counteract the external inversion torque, hyperinversion resulting in trauma to the lateral ankle ligaments is likely to occur.

PREVIOUS RESEARCH ON FUNCTIONAL ANKLE INSTABILITY

The classic work of Freeman et al[4] in 1965 suggested that sensory information arising from the ankle ligaments provides most of the proprioceptive information necessary to allow the body to produce appropriate motor responses to prevent or

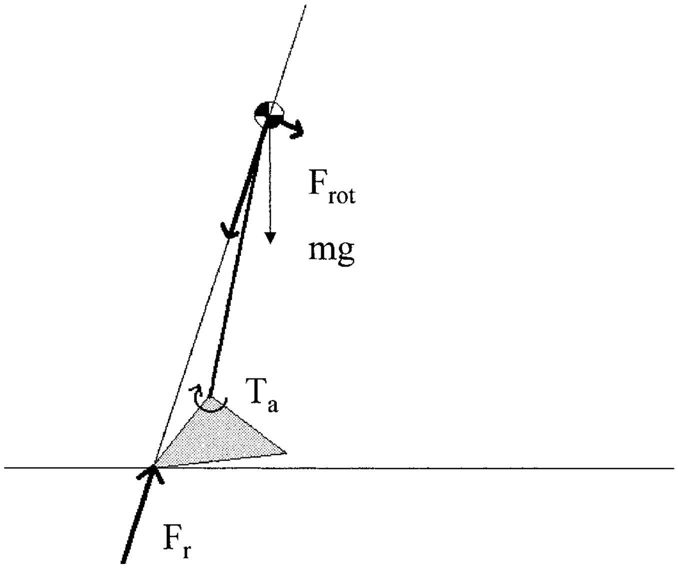

Figure 1. A model of the body as an inverted pendulum. The ankle is asymmetric due to muscular effort, which produces rotation of the center of gravity around the center of pressure. The ankle is not stuck to the ground, and it is not the ankle torque itself that rotates the body. F_{rot} indicates rotation force; mg, weight of the center of mass; T_a, ankle torque; and F_r, reaction force.

minimize injury. It was hypothesized that injury to the ankle ligaments also resulted in damage to the sensory receptors in these ligaments. This led to the common use of rehabilitation techniques to improve coordination by improving proprioception in patients recovering from ankle sprains. Despite widespread acceptance, the theory of damage to the mechanoreceptor system and the value of rehabilitation in restoring proprioception after ankle sprain have not been confirmed through research. The concept of FI, however, should not be discounted because a purely mechanical view of chronic ankle instability seems inadequate. Rehabilitation activities designed to stimulate the proposed proprioceptive function of the ankle ligaments might be effective, but the mechanism by which this occurs is not clear.

Recent researchers have been unable to confirm that mechanoreceptors constitute the most important source of proprioceptive information from peripheral joints. Rather, current evidence suggests that information from a variety of receptor sources (cutaneous, joint, and muscular) is important for motor control. Anesthetizing the lateral ligaments of the ankle has very little effect on ankle-joint proprioception as measured by the ability to match reference positions; however, application of a simple ankle brace improves ankle joint-position sense.[5] This suggests that cutaneous receptors may be more important than ligament receptors in providing proprioceptive information at the ankle.

Impaired postural control is a predictor for ankle injury in previously uninjured soccer players.[6] Thus, impaired postural control, as measured by stabilometry, is a primary condition in injury-prone subjects. Proprioceptive damage caused by an ankle sprain (secondary alteration) may impair the feedback needed to retain well-functioning central motor programs. The injury might directly alter the motor programs so that abnormal, injury-related motor performance occurs when an ankle is perturbed.

Intense postural training, such as ankle-disk training, rede-

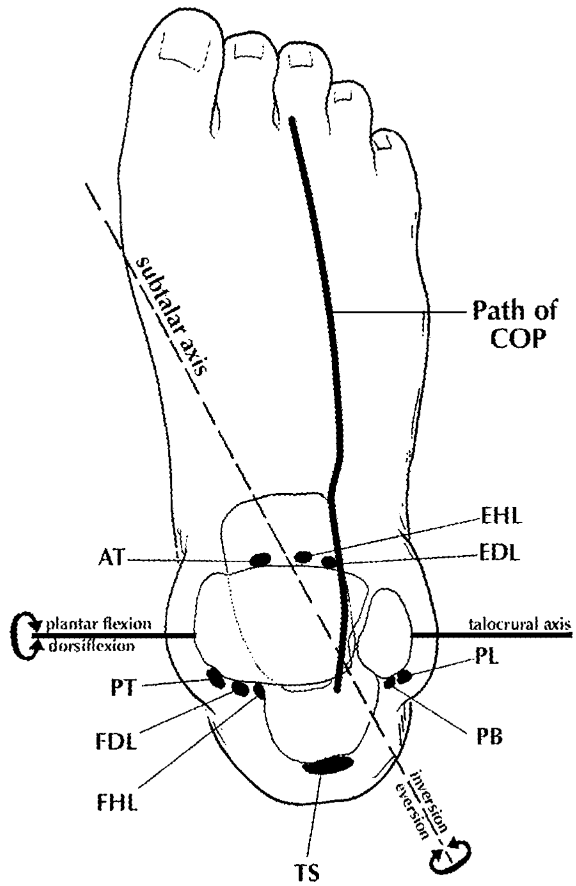

Figure 2. Transection of the ankle in the subtalar- and talocrural-joint axes. The different muscle tendons affect the ankle by their strength and position. The posteromedial muscles are strongest and counteract the force shown by the path of the center of pressure. COP indicates center of pressure; EHL, extensor hallucis longus; EDL, extensor digitorum longus; AT, anterior tibialis; PT, posterior tibialis; FDL, flexor digitorum longus; FHL, flexor hallucis longus; TS, tendon sheath; PL, peroneus longus; and PB, peroneus brevis.

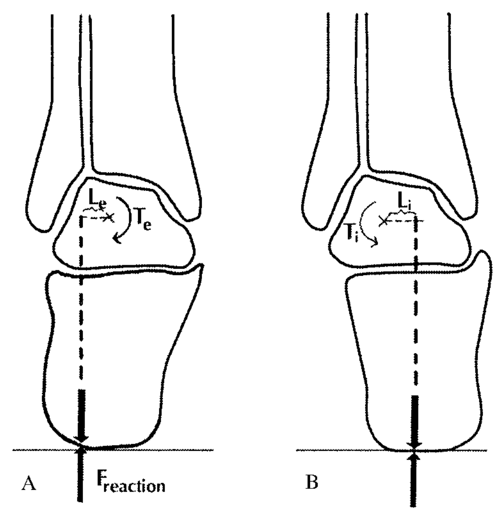

Figure 3. The subtalar-joint axis passes through the talus. A, Normally, an external everting torque is produced by the reaction forces acting around an everting lever arm (L_e). B, If the ankle is inverted, the reaction force might produce inversion through an inversion lever arm (L_i). T_e indicates external everting torque; T_i, external inverting torque; and $F_{reaction}$, reaction force.

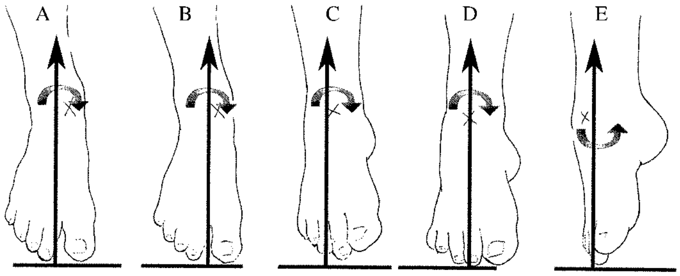

Figure 4. This series of drawings shows the A, neutral; B, everted; and C-E, inverted positions. The subtalar-joint axis is marked just medial to the anterior tibial tendon. The inverted foot moves the axis laterally to the line of action of the reaction force, leading to a potentially dangerous situation: giving way.

velops postural-correction patterns. With rehabilitation, Sheth et al[7] showed a change in pattern of muscle-reaction time such that a delay was seen for the anterior and posterior tibial muscles, which would be favorable for suitable qualitative correction of external inversion torque. This might provide a synergistic approach for avoiding inversion ankle sprains.

Patients with chronic lateral instability of the ankle have prolonged reaction time compared with healthy controls.[8] No differences, however, were found between sides when comparing reaction times in patients with unilateral instability. A stimulus-response threshold to different degrees of ankle inversion has been found in the peroneus latency response,[9] and the reflex pathways probably do not vary regardless of the angle of tilt.

Lentell et al[10] concluded that muscular weakness is not a major contributing factor in the chronically unstable ankle, but muscular imbalance has been shown to be an important predictor for injury.[11] Ankles with greater plantar-flexion strength and a smaller dorsiflexion-to-plantar-flexion ratio had a higher incidence of inversion ankle sprain. Similarly, individuals with an elevated eversion-to-inversion strength ratio had a higher incidence of ankle-inversion injury.[11]

During the swing phase of gait, the process of neuromuscular preparation for the subsequent weight-bearing stage of the gait cycle is important to ankle stability. Although injury does not typically occur in the swing phase, inappropriate positioning of the lower limb before heel strike would appear to increase the potential for injury. Once the foot reaches the ground, the line of action of the reaction force is determined and mainly related to the position of the foot in relation to the COG and inertia. If the foot is held in an inverted position when it reaches the ground, an external-inversion load is placed upon the joint, increasing the likelihood of injury.

Once weight bearing begins, the lag time to produce an effective recovery movement via the proprioception-neuromuscular complex (mechanoreceptor response time plus the electromechanical delay) is almost as long as the stance phase of running. This suggests that the most important issue to FI might be preprogrammed motor patterns and physiologic reactions to postural perturbations. Postural control is hierarchically organized,[12–14] so that complex locomotor movements are broken down into much simpler, stereotyped patterns. Nashner[15] proposed 3 principles for postural control: (1) rapid postural adjustments organized into a limited number of synergetic arrangements and fixed patterns, each of which is movement specific; (2) synergetic organization appears to be performed automatically by local mechanisms using receptor information; and (3) adaptation of responses is due to motor training, in which voluntary control is replaced by automatic movement sequences.

Tropp[16] and Perrin et al[17] emphasized the special role of the ankle in the control of both static and dynamic balance and the dominance of postural corrections at the hip joint in the presence of unstable ankles. The hip strategy of postural control includes larger corrective motions and results in higher shear forces with the ground.[15] Stabilometry has also shown greater COP trajectories with postural corrections at the hip. This is the biomechanical expression of wide segmental motions, which usually is seen as an increase in body sway. Hip strategy creates large shear forces with the ground, which may increase ankle inversion and result in the ankle giving way.[3]

PRACTICAL ASPECTS IN SPORTS MEDICINE

When assessing the chronically unstable ankle, it is important to differentiate between FI and MI. Instability related to pathologic laxity must be treated accordingly; however, FI lacks any clear relation to laxity. In a systematic review of the literature concerning the prevention of ankle sprain,[18] several Swedish studies are referenced. This raises the question as to whether these results can be generalized to other sport populations and countries. Most findings suggest that special emphasis on proprioception and ankle strengthening should be considered. I suggest that coordination training should include activities that provoke ankle inversion and eversion and should be performed for at least 2 months. Such efforts are aimed at improving neuromuscular performance and reducing ankle-injury rates.

After an injury, ankle taping or bracing can be used to avoid excessive inversion of the foot during the swing phase of gait (before foot contact) or protect against inversion torque (or both). Ankle taping and bracing have been found effective for injury prevention.[19] The mechanism could be a combination of keeping the unloaded foot in a neutral position and counteracting unexpected inversion torque; however, if the ankle is totally stiff, ankle synergy is prevented and hip synergy dominates. Taping or bracing may also provide protection by improving proprioception at the ankle through stimulation of cutaneous receptors. Conventional orthoses do not appear to have negative effects.

SUGGESTED DIRECTIONS OF FUTURE RESEARCH

When dealing with injuries and diseases of the locomotor system in general and bone and joint problems in particular, one is met by the message ‘‘stay active.’’ Our attitude toward physical activity and sports has changed. Many adults who were not raised to be active in general sports now perform various types of physical exercise. We see many ankle-joint injuries caused by jogging, aerobics, and other fitness programs. Certainly, these injuries are mostly benign and are probably counterweighted by the positive effects of exercise; however, we should find a way to decrease the incidence of such injuries.

Functional instability must be considered a viable cause of residual ankle disability and instability.[20] Even if neuromuscular deficits are identified, the clear mechanism of injury and the best methods of prevention are yet to be elucidated. I suggest that the main factor in FI is a change in coordination, mainly due to transition from ankle synergy to hip synergy during postural corrections. This may be combined with a tendency to invert the foot during the swing phase of the gait cycle and an inability to handle potentially dangerous situations during the stance phase. We do not know whether a local mechanoreceptor injury or muscle-strength imbalance contributes to chronic ankle instability, but coordination training and proprioceptive training are clearly the treatments of choice and can help prevent recurrent sprains. Further studies should focus on the importance of ankle position during the swing phase of gait[21] and potential alterations of motor programs with an increased risk for ankle-joint injuries.

ACKNOWLEDGMENTS

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